

EQUIPMENT

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DETERMINATION OF THE SPECIFIC COMPACTION PRESSURE OF CLAY MATERIALS IN BELT VACUUM PRESSES

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Questions concerning the improvement of the equipment design, specifically, belt vacuum presses, for the production of clay materials are elucidated. The basic relations for calculating the specific compaction pressure, taking account of the coefficients of proportionality and the plasticity of the material, are examined.

The development of new high capacity and cost effective equipment for producing porcelain and ceramic articles as well as efficient operation of this equipment are possible when sufficiently accurate methods are available to calculate the forces in the units of a machine, the power of the drives for the units, and the pressing forces for compacting the mass in vacuum presses and for determining the optimal press operating regimes.

The mechanical equipment used for the production of porcelain and porcelain-glazed articles, as a rule, is manufactured without the mechanisms and devices which make it possible to regulate the operating regimes. This has the effect that in many cases the machines are operated either with an overload, resulting in intensive wear of the machine and accidental breakdown, which in practice makes it necessary to create an extra operating regime for the machine, degrading productivity and the quality of the raw-materials processing, or a regime with underloading, which results in underutilization of the machine capacity.

In this connection, in the last few years preference has been given to methods for calculating clay-processing and forming machines in which the close relation between the rheological properties of the ceramic pastes, the energy consumption for processing and forming the pastes, and the production capacity of the equipment are taken into account together with the required optimal specific compaction pressure.

According to modern ideas, the clay paste worked in a machine passes through “conventional channels” of different geometric shape, which depend on the shape of the machine

parts which deform the clay [1]. In a continuous belt vacuum press the porcelain or ceramic pastes passes successively through a screw channel, consisting of a cylindrical housing and a worm, conical, wedge-shaped and, depending on the article being formed, a rectangular, ring-shaped, and slit channels.

Degassing the paste is necessary, since when materials are finely ground and clay materials are dissolved and undergo primary processing, the paste becomes enriched with air which degrades the shaping properties of the paste. In porcelain articles fabricated from poorly degassed paste the open porosity content is elevated (0.5–1.5%), as a result of which their light transmission decreases. The volume of air is 5–15% in freshly prepared paste and 0.3–4.0% after degassing [1].

Degassing increases the plasticity and improves by 2–3% the shaping properties of the paste with a lower quantity of plastic clay, which increases the whiteness of the articles. Degassing the mass decreases textural nonuniformity, increases plasticity, and improves the shaping properties of pastes, eliminates the fluctuations of the paste by almost a factor of 3, and increases the mechanical strength of the green parts up to 5 MPa [2]. This decreases the amount of breakage and rejects in production, decreases water absorption of the finished articles, and increases the light transmission and mechanical strength as well as the chemical resistance. Up to 90% of the power consumed by the press goes to the main operation of the press (extrusion and mixing of the paste) and up to 10% goes to shaping the blank. The normal heating of the paste in the press should not exceed 4–6°C. At elevated heating temperatures a blank can undergo stratification [2].

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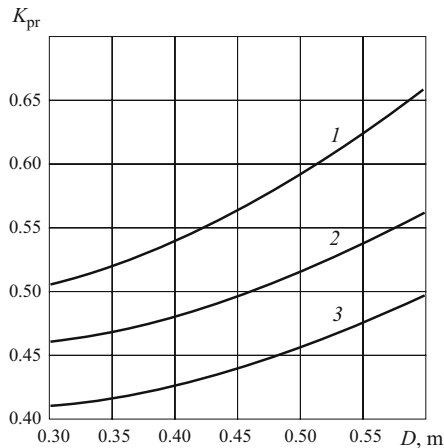


Fig. 1. Proportionality coefficient K_{pr} versus the plasticity coefficient K_{pl} : 1) $K_{pl} = 1.15$ (stiff clays); 2) $K_{pl} = 1$ (clays with average stiffness); 3) $K_{pl} = 0.875$ (highly plastic clays).

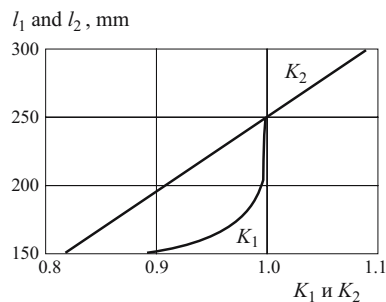


Fig. 2. Coefficients K_1 and K_2 versus the head length l_1 and outer die length l_2 .

In order to design belt vacuum presses it is necessary to know the type and dimensions of the articles being shaped, the characteristics of the ceramic paste being shaped (plasticity and moisture content), the required production capacity, and the approximate diameter of the worm blade that squeezes out the paste. The length of the head and the outer die of the press are initially assumed to be approximately the same as the diameter of the worm, by analogy with existing machines, and are refined during further design and fabrication [3].

To design presses it is necessary to determine the specific compaction pressure, which depends on the physical and mechanical properties of the paste (primarily its plasticity), the diameter of the cylinder of the press (worm), the length of the head and outer die as well as on the moisture content of the paste [4].

The specific compaction pressure (MPa) can be calculated according to the formula

$$P = 0.1K_1 K_2 (0.215W^2 - 10.62W + 130.5 + 11.8D^2), \quad (1)$$

where K_1 and K_2 are coefficients which take account of, respectively, the length of the head and outer die, which can be

TABLE 1.

Head length l_1 , m	K_1	Outer die length l_2 , m	K_2
0.150	0.878	0.150	0.820
0.175	0.980	0.175	0.866
0.200	0.988	0.200	0.910
0.225	0.995	0.225	0.955
0.250	1.000	0.250	1.000
0.275	1.010	0.275	1.044
0.300	1.020	0.300	1.090

determined using the data presented in Table 1; W is the moisture content of the ceramic paste, %; and, D is the diameter of the squeeze-out blade of the worm, m.

As the moisture content of the paste increases, the required specific compaction pressure decreases. According to the relation (1), it also depends on the diameter of the squeeze-out blade of the worm.

Taking account of the areas of the transverse cross-section of the worm F_1 and the transverse cross-section of the blank being shaped, i.e., the cross-section of the outer die of the press F_2 , as well as the length of the head of the press and the length of the outer die, the formula for determining the specific compaction pressure can be written as

$$P = \left(P_0 + K_{pr} \frac{F_1}{F_2} \right) \times 0.1 = \left(P_0 + K_{pr} \frac{\pi D^2}{4F_2} \right) \times 10^5, \quad (2)$$

where P_0 is the specific pressure neglecting the influence of the dimensions of the press, Pa; D is the diameter of the squeeze-out blade of the worm, m; F_1 is the transverse cross-sectional area of the squeeze-out blade of the worm, m^2 ; F_2 is the cross-section of the outer die at the exit, m^2 ; K_{pr} is the coefficient of proportionality, which depends on the plasticity of the clay paste being shaped and the diameter of the worm, determined from data presented in Fig. 1 as a function of the plasticity of the blank.

The plasticity of the clay raw material is determined according to GOST 21216.1-75. In accordance with this standard, clay masses are divided into the following groups according to plasticity: high plasticity, which we shall conventionally call category (1), with plasticity coefficient (number) 25, average plasticity — category (2) with plasticity coefficient 7 – 25, and low-plasticity, stiff — category (3) with plasticity coefficient 3 – 7.

The proportionality coefficients as a function of the plasticity coefficient and diameter of the squeeze-out blade of the worm are presented in Fig. 1.

The value of P_0 (Pa) can be expressed as a quadratic polynomial:

$$P_0 = (0.215W^2 - 10.62W + 130.5) \times 10^5, \quad (3)$$

where W is the moisture content of the mass being shaped, %.

Taking into consideration the coefficient K_1 which accounts for the change in the head length and the coefficient K_2 which accounts for the change in the length of the outer die, the compaction pressure can be determined from the relation

$$P = K_1 K_2 K_{pl} \left(0.215W^2 - 10.62W + 130.5 + K_{pl} \frac{\pi D^2}{4F_2} \right).$$

In summary, to design belt vacuum presses, calculate the production capacity, the diameter of the squeeze-out blade of the worm, the length of the head and outer die, and the specific compaction pressure, it is necessary to take account of the types and dimensions of the articles being shaped as well

as the characteristics of the ceramic paste (plasticity and moisture content).

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